

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) DIE ASSEMBLY

(71) We, ETIYL CORPORATION, a Corporation organised under the laws of the State of Virginia, United States of America, of 330 South Fourth Street, Richmond, State of Virginia, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a die assembly for the extrusion of thermoplastic material to produce lay-flat plastic tubing.

Bottom fed dies for extruding lay-flat plastic tubing are commonly used to produce thin walled polyethylene tubing which may be later converted to polyethylene film. Certain of these dies have been made by assembling one or more components in a vertically arranged stack to produce a bottom fed die assembly. An exemplary die of this type is shown in U.S. Patent Specification No. 2,937,402; the die is made by bolting together a number of individual components into a unitary assembly. In dies used for manufacturing thin, lay-flat polyethylene tubing it is not particularly critical that the flow passages be extremely smooth and free from areas where stagnation in the plastic melt may occur. Further, it is not essential that mating surfaces between the individual components of the die assembly be tightly coupled to prevent migration of the molten thermoplastic material in between these mating surfaces, since polyethylene is not particularly heat sensitive and thus does not char or decompose too readily under normal extrusion conditions. However, in the manufacture of polyvinyl chloride film the art has been faced with a difficult problem caused by the high heat sensitivity of polyvinyl chloride. When retained in a die for even a short period of time polyvinyl chloride can degrade and carbonize. This produces discoloration of

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the melt and produces catalytic degradation of the polyvinyl material flowing through the die passages.

Thus there is a recognized need in the art for a die assembly which provides a minimum of areas wherein the polyvinyl chloride can stagnate and decompose. Additionally, there is a need to provide a stacked die which can be assembled under extremely high pressures and which has very closely machined and ground mating surfaces between the abutting sections to prevent intrusion of any molten plastic material into the areas between the mating surfaces, thereby preventing thermal decomposition and subsequent fouling of the thermoplastic material flowing through the die.

According to the present invention there is provided a die assembly suitable for use in the extrusion of thermoplastic material for the production of lay-flat plastic tubing, which assembly comprises, a die holder having an axial passage which is frusto-conical and divergent in the direction of extrusion, a spider seated on and coupled to the die holder, the spider having a conical projection disposed within the frusto-conical passage in the die holder in such a manner that the projection and the wall of the passage define a frusto-conical annular passage, and the spider having passing through it a plurality of circumferentially spaced passages said passages being separated by axially extending spokes, said spokes being sufficiently thin and having a tapered portion at each end of a sufficiently small angle such that the flow of thermoplastic material is substantially unimpeded and areas of turbulence at the ends of said spokes are thereby avoided, and communicating with the frusto-conical annular passage, a die cup seated on and coupled to the spider and having an axial passage which is frusto-conical and divergent in the direction of extrusion, a mandrel seated on and coupled

to the spider, one part of the mandrel being frusto-conical and disposed within the frusto-conical passage in the die cup in such a manner as to define a frusto-conical annular passage, which passage communicates with the passages in the spider; and another part of the mandrel projecting beyond the die cup; an adjustable annular cup lip seated on and coupled to the die cup, the inner surface of the cup lip being spaced from that outer surface of said other part of the mandrel so as to define an annular orifice through which thermoplastic material may be extruded, the mandrel being coupled to the spider by a centrally positioned bolt tightened with a torque force of 2,000 to 12,000 foot pounds and the die holder, spider, die cup and cup lip being tightly coupled together by threaded fastening means, said die assembly having the capability to resist significant deformation at thermoplastic material pressures up to 7,000 p.s.i.

A preferred embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which:—

Figure 1 is a plan view of a tubular film die assembly constructed in accordance with the present invention;

Figure 2 is an axial cross-sectional view of the die taken along the line 2-2 of Figure 1,

Figure 3 is a cross-sectional view of the die taken along the line 3-3 of Figure 2,

Figure 4 is a cross-sectional view of the die taken along the line 4-4 of Figure 2,

Figure 5 is a vertical sectional view through a spider or spoke portion of the die depicted in Figure 4 taken along the line 5-5; and

Figure 6 is a vertical sectional view through a spider or spoke section of a prior art die assembly.

Referring now to Figures 1 and 2, the die assembly of the present invention, designated generally by the numeral 10, includes a die holder or base 11 at the bottom thereof. The die holder 11 is provided with a generally cylindrical axial passage 12 which merges into an upwardly diverging conical cavity 13 opening into the upper face of the die holder. The base of the die holder 11 is provided with a shoulder 14 which is adapted to be mounted on the elbow of a plastics extruder (not shown) and coupled thereto by a quick connect clamp. A generally cylindrical flange 15 extends out from the upper portion of the die holder 11 and has a plurality of evenly spaced openings 16 adjacent its outer edge. The flange 15 may be attached to the die holder 11 by means of welding or it may be integrally formed with the die holder. An annular recess 17 is provided in the outer wall of the die

holder 11 and is covered by a cylindrical band 18 attached to the outer wall by welding or other suitable means. Threaded openings 60 are provided on opposite sides of the band 18 to permit steam or other heating fluid to be circulated through the annular recess 17 to heat the die holder. The die holder 11 is provided with an annular raised shoulder 20 on its upper face.

A generally cylindrical spider 19 is mounted on top of the die holder 11. Shoulder 20 is received in a generally cylindrical recess 21 provided in the bottom face of spider 19. The mating surfaces on the top of the shoulder 20 and the bottom of the recess 21 are machined and ground to an extremely smooth surface and a highly accurate fit is attained in these abutting surfaces to prevent molten plastic material from penetrating between these surfaces. The vertical walls of the shoulder 20 and the recess 21 must be machined and ground with very close tolerance to provide a perfect fit so that there will be no misalignment between the joining interior walls of the die holder 11 and the spider 19.

The spider 19 has a conical extension 22 extending from its bottom face. The extension 22 has attached to the spider 19 by means of a threaded boss 23 received in axially aligned threaded opening 23a provided in the bottom face of the spider 19. The conical extension 22 extends into the conical cavity 13 provided in the die holder 11. The outer wall of the conical extension 22 together with the wall of the conical cavity 13 define a generally conically shaped annular space 23 through which the thermoplastics material entering the opening 12 flows up into the spider 19 of the die when the die is in use. As can be seen more clearly in Figures 3, 4 and 5 a plurality of spiders or spokes 24 connects the generally cylindrical outer wall portion 25 of the spider 19 with the inner cylindrical portion 26. A plurality of evenly spaced, arcuately shaped, longitudinal passages 27 are provided in the spider 19 between the outer wall portion 25 and the inner cylindrical portion 26. These openings 27 provide passages for the thermoplastic material flowing from the conical shaped space 23 in the die holder 11 up through the spider 19. The outer wall portion 25 of the spider 19 is provided with a generally rectangular shaped annular recess 28 which is covered by a cylindrical band 29 that is welded to the wall portion to provide maximum strength. Steam, hot oil, or other heat transfer media may be circulated through recess 28.

The top surface of the spider 19 is provided with a raised shoulder having an inner portion 30a and an outer portion 30b separated by an annular opening having the same width as the passages 27 which define

the spokes 24 in the spider 19. A small radial passage 31 having a threaded outer portion extends from the outer wall of the spider 19 to communicate with an axially aligned bore 32 provided in the top of spider 19.

A separate die cup 33 is mounted on top of the spider 19. The die cup 33 has a large axial passage 34 therethrough which defines the interior wall of the die cup. The lower portion of the passage 34 is generally cylindrical in shape, the intermediate portion is conically shaped with the walls diverging in an upward direction and terminating in a section having a generally cylindrical wall at the top of the die cup 33. An annular recess 35 is provided in the bottom surface of the die cup 33. This recess receives and fits tightly down over the outer annular shoulder portion 30b provided on the top of the spider 19. A precision fit between these surfaces is necessary to provide a seal against penetration of thermoplastic material in between these mating surfaces.

A plurality of threaded bores 36 are provided in the bottom surface of the die cup 33 adjacent its outer edge. A plurality of bolts 37 extend through the openings 16 provided in the flange 15 of the die holder 11 and have their threaded ends received in the threaded bores 36 in the die cup 33. A generally cylindrical spacer sleeve 38 surrounds each bolt 37 and extends from the upper surface of flange 15 to the bottom surface of the die cup 33. The sleeves are adjusted in length to provide a precision fit between the mating surfaces of the annular shoulder 20 and cylindrical recess 21 and the mating surfaces of the outer portion of the shoulder 30b and the annular recess 35. Bolts 37 should be torqued in order that the mating surfaces between the aforementioned shoulders and recesses are brought together with sufficient force so that the molten thermoplastic material cannot penetrate the interfacial area between these mating surfaces.

An annular recess 39 is provided in the outer wall of the die cup 33 and is covered by cylindrical sleeve 40 which forms a part of the outer wall of the die cup to provide an annular space for circulation of a heating media for the die cup. Opposite threaded openings 41-41 are provided in the sleeve for an inlet and outlet for the heating media.

A separate mandrel 43 is received in the opening 34 provided in the die cup 33. The mandrel 43 provides a recessed annular shoulder 44 on its bottom surface which seats against and mates with the outer portion 30b of the shoulder on top of the spider 19. The mandrel provides an axial cylindrical opening 45 therethrough which

receives a large socket head bolt 46. The threaded lower end of bolt 46 engages threads provided in the axial bore 32 in the top of the spider 19. A small axial passage 47 extends through the bolt 46 and communicates with the radial opening 31 in the spider by means of the axial counter-bore space provided at the bottom of the bolt. By means of radial opening 31 and passage-way 47 air can be supplied to inflate the thermoplastic tube produced by the die assembly 10 of the present invention. Bolt 46 is shown as having a socket head opening 48 recessed at the top.

An annular recess 49 is provided in the top surface of the mandrel 43 and is sealed by means of cover ring 50 to provide a closed space for circulation of a heating medium therethrough. The mandrel 43 has a shape which almost coincides to that of the opening 34 provided in the die cup, i.e. the lower portion of the mandrel outer wall surface is generally cylindrical and the intermediate central portion thereof is conical and outwardly diverging while the upper portion thereof is generally cylindrical in shape. The annular space remaining when the mandrel 43 is inserted in the opening 34 in the die cup provides a passageway with walls which converge thus resulting in an annular opening whose width decreases from the bottom of the assembly to the top thereof.

An annular cup lip 51 is seated on the top surface of the die cup 33 and held in position by a series of socket head bolts 52 which have their threaded ends received in threaded bore 42 provided in the top of the die cup 33. The cup lips 51 is provided with a depending annular skirt 53 surrounding the upper portion of the die cup 33. The skirt 53 is provided with a plurality of transverse threaded openings 54 evenly spaced around the skirt which receive a threaded bolt 55. The inner end of bolt 55 bears against the outer surface of the top section of the die cup 33. Bolts 55 are provided to position and to precisely adjust the spacing of the inner cylindrical wall 56 of the cup lip from the opposite cylindrical wall of the mandrel 43 to provide accurate control of the spacing of the orifice opening 57 through which thermoplastics material is to be extruded. A generally annular recess 58 is provided in the upper outer wall of the cup lip 51. The recess is sealed by annular band 59 to provide a sealed space for circulation of heating media to heat the cup lip 51.

In one exemplary construction of a die in accordance with the present invention, made for extruding lay-flat thermoplastic tubing from polyvinyl chloride resin, the die was sized to provide an extruded polyvinyl chloride tube diameter of eight inches

at the die orifice. The die holder 11 was fabricated to stand $4\frac{1}{2}$ inches in height. The spider 19 had an outside wall height of $3\frac{1}{8}$ inches. The die cup 33 and cup lip 52 had a combined height of $5\frac{1}{2}$ inches as measured from the bottom of the die cup to the level of the cup lip at the orifice opening 57. A space of $1/16$ inch separates the facing shoulders provided by the outer portion of the spider and both the opposed face of the die holder 11 and the die cup 33. When assembled the die had a height of $13\frac{1}{8}$ inches measured from the bottom face of the die holder 11 to the flat surface at the level of the orifice 57. The die was constructed of stainless steel which is resistant to the degradation products of polyvinyl chloride. The die may also be made of tool steel and chrome plated to resist corrosion.

In manufacturing the die components it is essential that the shoulder 20 be machined to have an extremely close and tight fit with the mating surface provided by the recess 21 in the spider 19. It is also essential that similar mating surfaces at the top of the spider, i.e., the shoulder portion 30b be machined to fit very tightly and very snugly with the annular recess 35 provided in the bottom of the die cup assembly. Also the shoulder portion 30a should be machined to fit precisely with the annular recess 44 in the bottom of the mandrel in order to provide an extremely tight fit of the mating surfaces of the die components to prevent any molten polyvinyl chloride from seeping into the interfacial area between these die components. Additionally the conical extension 22 of the spider should be tightly screwed onto the bottom of the spider to make sure that no plastic material penetrates between these mating surfaces.

In the die assembly of the present invention it is very important that the thickness of the spider or spokes 24 be kept to a minimum. The spokes 24 should not be any wider than required to provide the strength necessary to prevent them from breaking under the pressure of the molten plastics flowing up through the die assembly. As seen in Figure 6 the prior art spoke 61 narrow and long with a low angled tapered portion at each end thereof. This construction permits the thermoplastics material to achieve streamline flow over the spoke and does not cause any turbulence to be created in the plastic as it flows across the spoke. As seen in Figure 6 the prior art spoke 61 is generally elliptical in shape and has a width much greater than does the spoke 24 used in the die assembly of the present invention. As the plastic material flows over this type of spoke it produces an area of turbulence at the top of the spoke where stagnation can occur. This causes burning

and degradation of heat sensitive materials like polyvinyl chloride and produces a carbon mass 62 at the top of the spoke. Since many die assemblies used for polyethylene extrusion have generally elliptical spokes these die have not been found suitable for extrusion of polyvinyl chloride. The thin, long spokes 24 of the present die assembly also minimize production of so-called "gauge bands" in the film which are often produced by spokes of conventional dies such as shown in Figure 6. The present thin spoke 24 does not restrict the flow of plastic through the die lips to the extent that the thicker conventional spokes 61 do and this relatively little thinning of the wall of the tubular film occurs immediately above each of the spokes 24.

In assembling the die the spacers 38 should be carefully sized as stated hereinbefore to provide a tight fit between the mating surfaces of the three outer components of the die to prevent migration of thermoplastic material between the mating surfaces. If the sleeves 38 are made too short and too much torque is applied to the bolts 37 it will cause the mating surfaces between the die holder 11, spider 19, and die cup 33 to spring open slightly and permit thermoplastic material to enter the area between the mating surfaces where it will degrade and cause charring of the polyvinyl chloride which will further degrade the thermoplastic material passing through the die channels. If the sleeves 38 are too long, insufficient force will be applied to the mating surfaces between the foregoing components and this will also permit thermoplastics material to enter between these mating surfaces resulting in charring and degradation of the thermoplastics material flowing to the die lips. It is essential also that the large bolt 46 holding the mandrel 43 to the spider 19 be screwed into the spider 19 with sufficient force to prevent plastic from creeping into the mating surfaces 30a and 44. The bolt 46 must also be tightened and a sufficient force so that mandrel 43 has sufficient rigidity to resist the upward thrust produced by the viscous thermoplastic material flowing up out of the spider and pressing against the diverging conical wall surfaces of the mandrel 43. It has been found that it is necessary to torque the bolt 46 with a force which varies between 2,000 or 3,000 foot pounds torque and 12,000 foot pounds torque depending upon the size of the die in use. For a $3\frac{1}{2}$ inch extruder feeding polyvinyl chloride compound to a die having an orifice diameter of 8 inches it was found that the torque should be applied to the bolt 46 ranges from about 2,400 foot pounds to about 3,000 foot pounds. When using the exemplary die described in the foregoing

section (i.e. one 8 inch diameter) it was found that the torque applied to bolt 46 should be from about 2,400 to about 3,000 foot pounds of torque.

- 5 In order to resist the high forces encountered in extruding polyvinyl chloride it has been found that there should be a certain ratio maintained between the diameter "A" of the cylindrical portion of the body of the mandrel 43 adjacent to the spider 19 and the diameter "B" of the wall of the mandrel 43 adjacent to the annular cup lip 51. This ratio, representing the projected area across the mandrel 43, must be consistent with the available retaining force of bolt 46. That is, as the annular opening of the die increases this ratio must decrease to maintain a bolt size with practical torquing limits. The die of the present invention will effectively resist the upward thrusting forces of the thermoplastic material if the ratio for these two diameters (B/A) ranges from about 1.5/1 to about 2.0/1 with a 1.5 inch diameter bolt. If the ratio is kept in this range and the 1.5 inch bolt is torqued in the range of 2,400 to 2,800 foot pounds it will provide sufficient rigidity to the mandrel 43 to resist distortion by the lifting action of the thermoplastic material flowing through opening 34. Pressures as high as 7,000 p.s.i. have been used satisfactorily in the 8 inch die.

WHAT WE CLAIM IS:—

1. A die assembly suitable for use in the extrusion of thermoplastic material for the production of lay-flat plastic tubing, which assembly comprises, a die holder having an axial passage which is frusto-conical and divergent in the direction of extrusion, a spider seated on and coupled to the die holder, the spider having a conical projection disposed within the frusto-conical passage in the die holder in such a manner that the projection and the wall of the passage define a frusto-conical annular passage, and the spider having passing through it a plurality of circumferentially spaced passages said passages being separated by axially extending spokes, said spokes being sufficiently thin and having a tapered portion at each end of a sufficiently small angle such that the flow of thermoplastic material is substantially unimpeded and areas of turbulence at the ends of said spokes are thereby avoided, and communicating with the frusto-conical annular passage, a die cup seated on and

coupled to the spider and having an axial passage which is frusto-conical and divergent in the direction of extrusion, a mandrel seated on and coupled to the spider, one part of the mandrel being frusto-conical and disposed within the frusto-conical passage in the die cup in such a manner as to define a frusto-conical annular passage, which passage communicates with the passages in the spider; and another part of the mandrel projecting beyond the die cup; an adjustable annular cup lip seated on and coupled to the die cup, the inner surface of the cup lip being spaced from that outer surface of said other part of the mandrel so as to define an annular orifice through which thermoplastic material may be extruded, the mandrel being coupled to the spider by a centrally positioned bolt tightened with a torque force of 2,000 to 12,000 foot pounds and the die holder, spider, die cup and cup lip being tightly coupled together by threaded fastening means, said die assembly having the capability to resist significant deformation at thermoplastic material pressures up to 7,000 p.s.i.

2. A die assembly according to claim 1 wherein a portion of the interior wall of said die cup and a portion of the exterior wall of said mandrel define a generally conical, annular passageway the walls of which converge as said passageway approaches said annular orifice, to which orifice is thereby conveyed the flow of thermoplastic material.

3. A die assembly according to claim 1 or claim 2 wherein the passages through the die assembly present a smooth interior surface with no sharp turns.

4. A die assembly according to any one of the preceding claims wherein said bolt has a diameter of about 1.5 inches and the ratio of the diameter of the wall of said mandrel adjacent to said annular cup lip to the diameter of the cylindrical portion of the body of said mandrel adjacent to said spider is from 1.5 to 2.0.

5. A die assembly according to claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.

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1,253,454
3 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of
the Original on a reduced scale.

SHEET 1

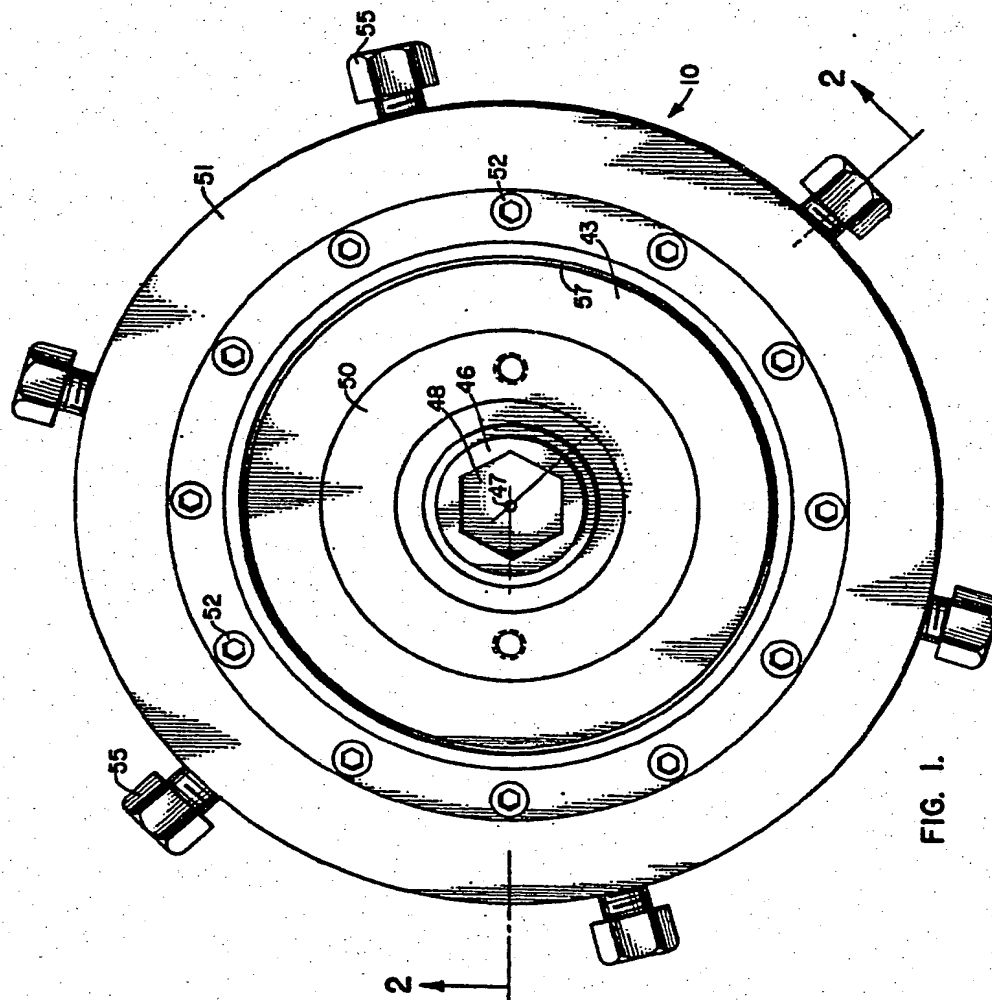
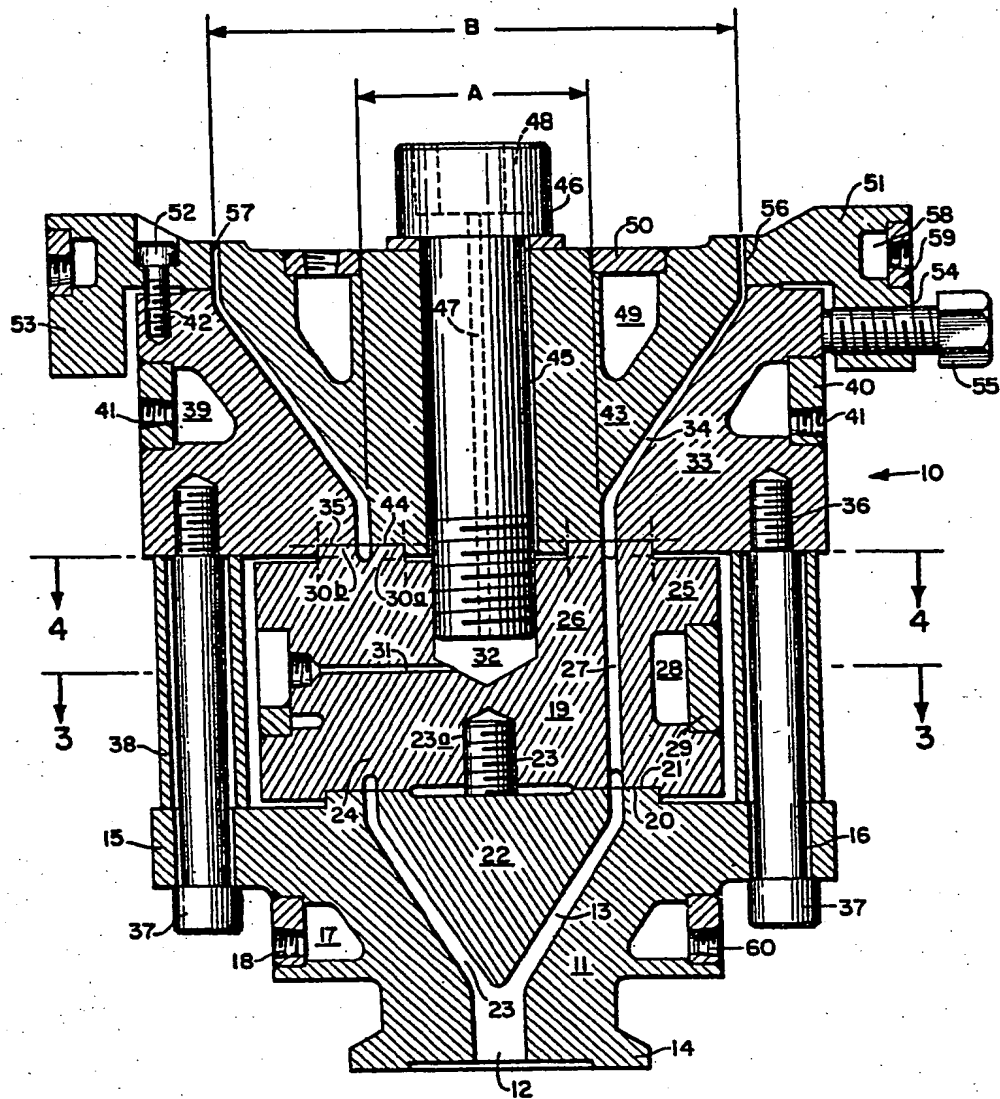


FIG. 1.

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3 SHEETS

COMPLETE SPECIFICATION
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SHEET 2



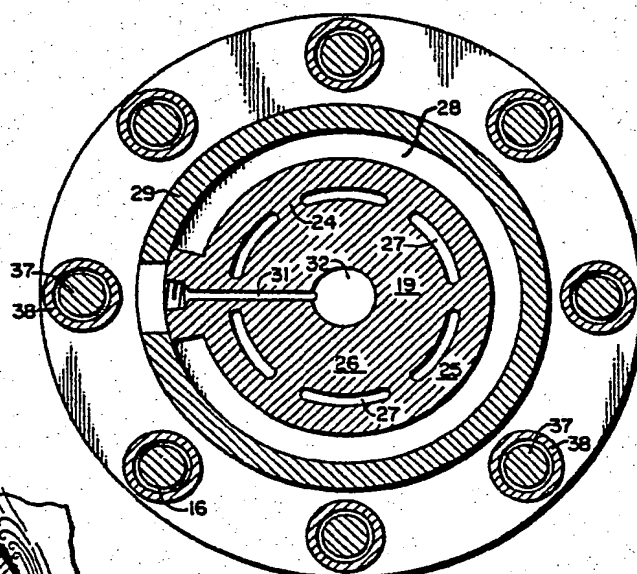


FIG. 3.

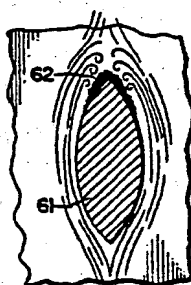


FIG. 6.

PRIOR
ART

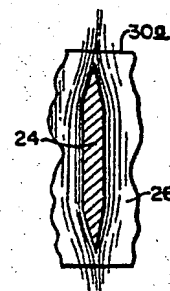


FIG. 5.

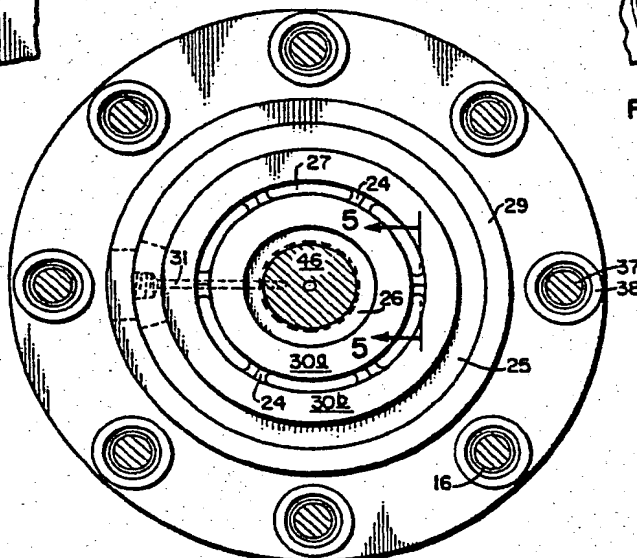


FIG. 4.